The leaf essential oil of *Juniperus formosana* (Taiwan) compared with *J. mairei* (Gansu, China) and *J. jackii*

Robert P. Adams
Biology Department, Baylor University, Box 97388, Waco, TX 76798, USA
Robert_Adams@baylor.edu

Chang-Fu Hsieh
Institute of Ecology and Evolutionary Biology, National Taiwan University,
Taipei 106, Taiwan

and

Ge-lin Chu
Institute of Botany, Northwest Normal University, Lanzhou, Gansu, 730070, China

ABSTRACT

The compositions of the essential oils of *Juniperus formosana, J. jackii* and *J. mairei* are presented. The volatile leaf oil of *J. formosana* (Taiwan) is dominated by α-pinene (44.0%), with moderate amounts of β-pinene (4.2%), myrcene (6.4%), β-phellandrene (5.3%), δ-cadinene (2.9%), germacrene D-4-ol (3.8%) and α-cadinol (4.1%). The oil shares the large concentration of α-pinene with *J. mairei* but has fewer compounds. *Juniperus formosana* contains several unique compounds, including sibirene, that is rare in *Juniperus* leaf oils. Each of these 3 species have a unique oil composition that broadly supports their phylogenetic differences Published on-line **www.phytologia.org** *Phytologia 96(1): 28-32 (Jan. 8, 2014)*. ISSN 030319430

KEY WORDS: *Juniperus formosana, J. f. var. mairei, J. mairei, J. jackii,* leaf essential oils, terpenes, taxonomy.

Recently, Adams and Schwarzbach (2012) have shown that *Juniperus formosana* Hayata and *J. formosana var. mairei* (Lemee and H. Lev) R. P. Adams and C.-F. Hsieh are not as closely related as previously thought. In fact, *J. f.* var. *mairei* (Gansu, China) was found in a clade (Fig. 1) with *J. jackii* (Rehder) R. P. Adams (North America), not with *J. formosana* (Taiwan). A minimum spanning network revealed (Adams and Schwarzbach, 2012) that *J. f.* var. *mairei* differs by 13 MEs from *J. formosana* (Taiwan) and 20 MEs from *J. jackii* (Fig. 2). Although Adams (2011) recognized *J. f.* var. *mairei*; recently, Adams and Schwarzbach (2012) recognized *J. mairei* as a distinct species.

The composition leaf essential oil of *J. mairei* (Gansu) have been reported (as *J. formosana* in Adams, Zhang and Chu, 1995, Adams, 2000) and the leaf essential oil of *J. jackii* was published by Adams, 2013 and Adams et al., 2010. Yu et al. (1994) reported on the leaf oil of *J. formosana* (*J. mairei*) from the China mainland. However, there appears to be no report on the leaf essential oil of *J. formosana* var. *formosana* from Taiwan. *Juniperus formosana* is endemic to Taiwan, except for one report of its occurrence in Kushan across the Taiwan (Formosa) Strait from Taiwan, on the China mainland (Adams, 2011). Adams, Zhang and Chu (1995) reviewed the literature, most of which reports on wood oil compositions.

The purposes of this paper are to report on the composition of the leaf essential oil of *J. formosana* from Taiwan and to compare it with the oils of two related species, *J. jackii and J. mairei*.

MATERIALS AND METHODS

Leaf materials: *J. formosana*, *Adams and Hsieh 8747-8749,* Hehuanshan, (Mt. Hohuan), Taiwan; *J. mairei* (*J. f.* var. *mairei*), *Adams* and *Chu 6772-6774, 6792*, near Jone, Gansu, China; *J. jackii*, *Adams 10287-10281* on serpentine, near Smith River, on Rowdy Creek Road, 2095 m, Del Norte Co., CA, USA. Voucher specimens are deposited in the herbarium, Baylor University.

Fresh, frozen leaves (200 g) were steam distilled for 2 h using a circulatory Clevenger-type apparatus (Adams, 1991). The oil samples were concentrated (ether trap removed) with nitrogen and the samples stored at -20°C until analyzed. The extracted leaves were oven dried (100°C, 48 h) for determination of oil yields.

The oils were analyzed on a HP5971 MSD mass spectrometer, scan time 1/ sec., directly coupled to a HP 5890 gas chromatograph, using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column (see Adams, 2007 for operating details). Identifications were made by library searches of our volatile oil library (Adams, 2007), using the HP Chemstation library search routines, coupled with retention time data of authentic reference compounds. Quantitation was by FID on an HP 5890 gas chromatograph using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column using the HP Chemstation software.

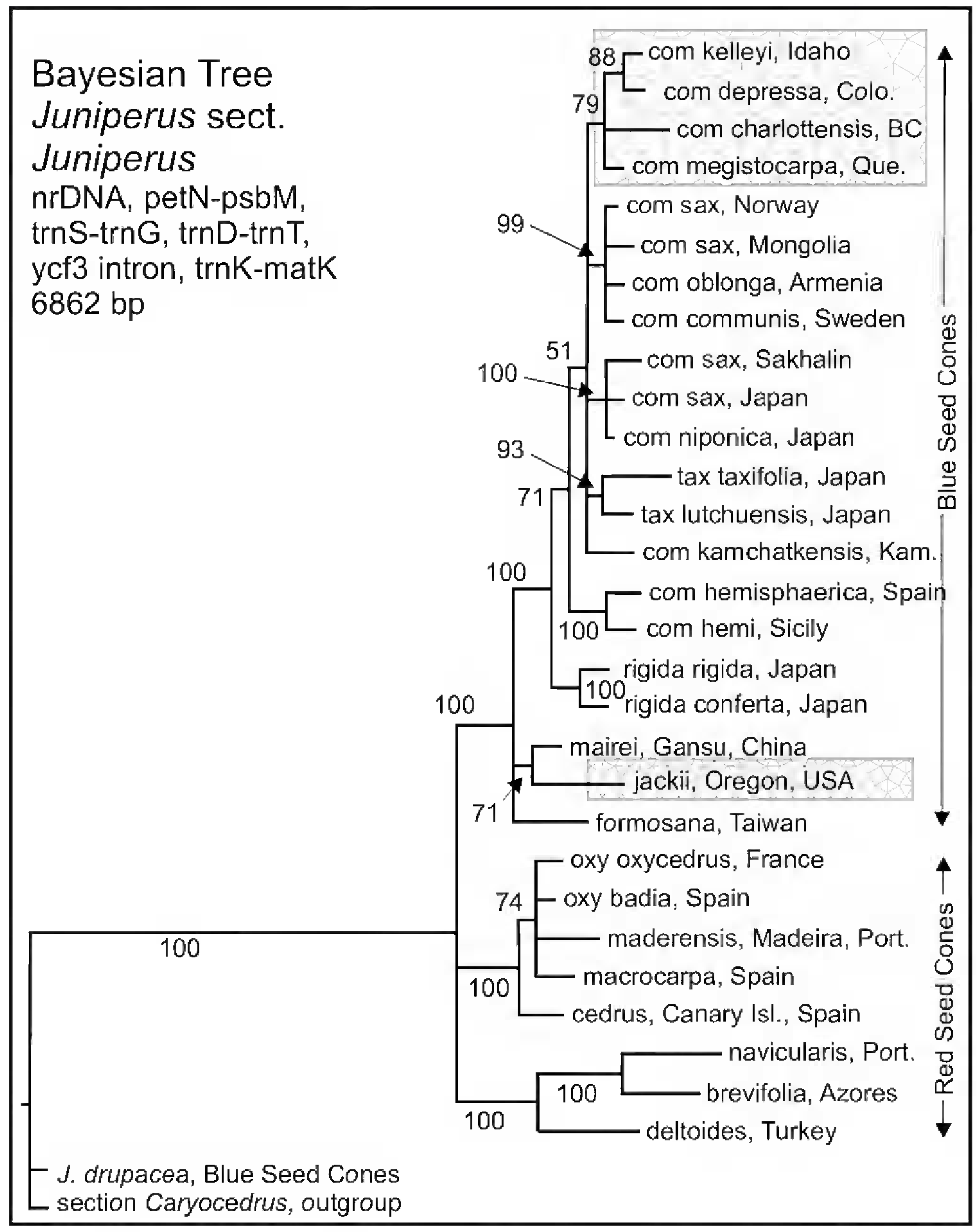

Fig. 1. Bayesian tree for *Juniperus* sect. *Juniperus*. Numbers at branch points are posterior probabilities. From Adams and Schwarzbach (2012).

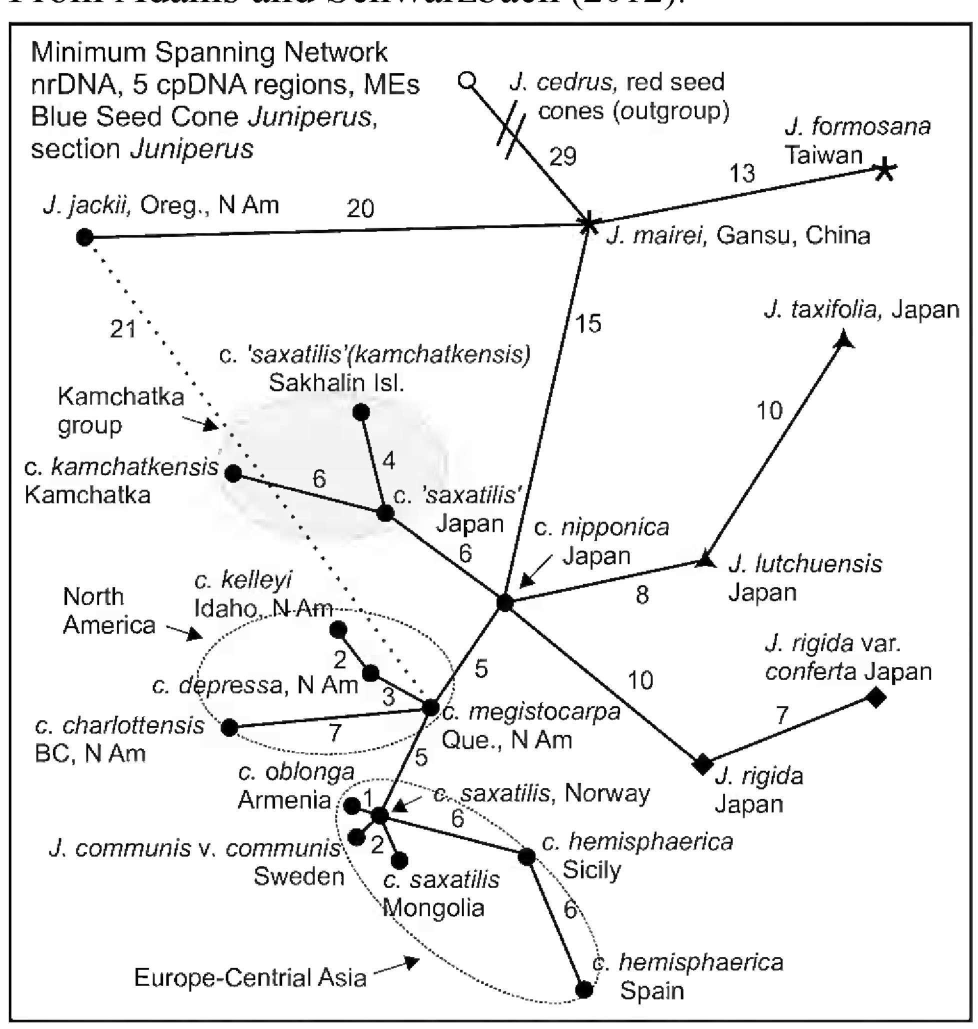

Figure 2. Minimum spanning network (MSN) of the blue seed cone junipers. *J. cedrus* is the nearest of the red seed cone species. Note that *J. mairei*, Gansu, differs by 13 MEs from *J. formosana* (Taiwan) and 20 MEs from *J. jackii*. Adapted from Adams and Schwarzbach (2012).

RESULTS AND DISCUSSION

The volatile leaf oil of *J. formosana* (Taiwan) is dominated (Table 1) by α-pinene (44.0%), with moderate amounts of β-pinene (4.2%), myrcene (6.4%), limonene (3.5%), β-phellandrene (5.3%), δ-cadinene (2.9%), germacrene D-4-ol (3.8%) and α-cadinol (4.1%). The oil shares the large concentration of α-pinene with *J. mairei* but has fewer compounds (Table 1). *Juniperus formosana* contains several unique compounds: naphthalene, β-cubebene, sibirene, trans-cadina-1(6),4-diene, sandaracopimarinal and trans-totarol. Sibirene is rare in *Juniperus* leaf oils (Adams, 2011).

The oil of *J. mairei* is more similar to *J. formosana* than to *J. jackii* (Table 2), reflecting the minimum spanning network (Fig. 2), rather than the Bayesian tree (Fig. 1). However, it contains several unique (to this small set of 3 species) compounds: 3-me-3-butenol butyrate, unknown terpene alcohol (at KI 1092), borneol, unknown 1198, prenyl hexanoate (1.1%), (E)-methyl iso-eugenol, (E)-nerolidol, geranyl butanoate and oplopenone (Table 1).

In contrast, the oil of *J. jackii* has a moderate amounts of α-pinene (16.1%), δ-3-carene (17.9%), β-phellandrene (13.4%), myrcene (3.2%), limonene (6.6%), terpinolene (3.2%), and germacrene D (4.1%). Its oil contains several unique compounds: δ-3-carene, p-mentha-1,5-dien-8-ol, thymol, methyl ether, methyl myrtenate, α-terpinyl formate, β-elemene, γ-muurolene, α-cadinene, germacrene B, salvial-4(14)-en-1-one, cyclohexadecanolide, manoyl oxide, abietatriene and isoabienol.

These 3 species have unique oil compositions that broadly support their phylogenetic differences seen in DNA sequencing (Figs. 1, 2).

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Table 1. Comparison of the leaf oils of *J. formosana* (Taiwan), *J. mairei* (Gansu, China) and *J. jackii* (North America). Compounds in bold face appear to separate taxa.

KI	Compound	*formosana* Taiwan	*J. mairei* Gansu	*jackii* N. Am.
851	(E)-2-hexenal	1.2	t	0.2
921	tricyclene	t	t	t
924	α-thujene	t	0.1	t
932	**α-pinene**	**44.0**	**55.5**	**16.1**
945	α-fenchene	t	t	0.3
946	camphene	0.4	0.5	0.3
953	thuja-2,4-diene	-	t	-
961	**verbenene**	**-**	**1.4**	**0.3**
969	sabinene	0.1	0.2	0.1
974	β-pinene	4.2	2.5	1.9
988	myrcene	6.4	5.7	3.2
1001	δ-2-carene	2.6	0.7	0.2
1002	α-phellandrene	0.7	0.5	2.2
1008	**δ-3-carene**	**-**	**-**	**17.9**
1020	p-cymene	0.3	1.1	1.1
1024	limonene	3.5	2.4	6.6
1025	**β-phellandrene**	**5.3**	**2.3**	**13.4**
1044	(E)-β-ocimene	0.2	-	0.3
1054	γ-terpinene	t	-	0.1
1061	3-me-3-butenol butyrate	-	0.4	-
1086	terpinolene	0.6	0.7	3.2
1092	C10-OH ,<u>96</u>,109,137,152	-	1.3	-
1114	endo-fenchol	-	0.7	-
1118	cis-p-menth-2-en-1-ol	0.1	-	0.2
1122	α-campholenal	-	0.3	0.2
1132	cis-limonene oxide	-	-	0.1
1136	trans-pinocarveol	-	0.3	0.2
1140	trans-verbenol	0.1	0.5	0.2
1145	camphene hydrate	-	0.3	-
1165	borneol	-	0.3	-
1166	p-mentha-1,5-dien-8-ol	-	-	0.4
1174	terpinen-4-ol	t	0.4	0.7
1178	naphthalene	0.6	-	-
1179	p-cymen-8-ol	-	0.2	0.3
1186	α-terpineol	0.1	0.6	0.3
1195	myrtenol	-	0.3	0.4
1198	C10-al,<u>95</u>,121,139,154	-	0.5	-
1204	verbenone	-	0.1	0.3
1215	trans-carveol	-	0.1	0.4
1223	citronellol	0.3	0.4	-
1232	thymol, methyl ether	-	-	0.2
1235	cis-chrysanthenyl acetate	-	0.2	-
1249	piperitone	-	0.8	-
1260	3-me-3-butenol hexanoate	0.1	0.9	-
1284	bornyl acetate	0.7	1.1	0.5
1292	**prenyl hexanoate**	**-**	**1.1**	**-**
1293	methyl myrtenate	-	-	0.2
1302	α-terpinyl formate	-	-	1.0
1324	myrtenyl acetate	-	t	1.6
1332	cis-piperitol acetate	-	0.2	-
1346	α-terpinyl acetate	-	0.1	0.9
1374	α-copaene	0.3	0.2	-
1385	trans-myrtanyl acetate	-	-	t

KI	Compound	*formosana* Taiwan	*mairei* Gansu	*jackii*[1] N. Am.
1379	geranyl acetate	-	t	-
1387	β-cubebene	0.2	-	-
1391	β-elemene	-	-	0.3
1400	**sibirene**	**0.7**	**-**	**-**
1417	(E)-caryophyllene	0.9	0.7	0.4
1452	α-humulene	0.4	0.4	0.5
1465	cis-muurola-4(14),5-diene	-	-	t
1473	isobornyl-n-butanoate	-	0.2	-
1475	trans-cadina-1(6),4-diene	0.2	-	-
1478	γ-muurolene	0.3	-	t
1480	germacrene D	1.5	1.2	4.1
1491	(E)-methyl iso-eugenol	-	0.2	-
1493	epi-cubebol	0.6	-	0.3
1499	γ-muurolene	-	-	0.6
1500	α-muurolene	0.6	0.1	-
1503	germacrene A	-	-	t
1513	γ-cadinene	1.3	2.2	1.2
1514	cubebol	1.3	-	-
1522	δ-cadinene	2.9	0.5	2.2
1537	α-cadinene	-	-	0.2
1548	elemol	-	-	t
1559	germacrene B	-	-	0.5
1561	**(E)-nerolidol**	**-**	**0.2**	**-**
1561	**geranyl butanoate**	**-**	**0.4**	**-**
1574	germacrene D-4-ol	3.3	0.6	0.9
1582	caryophyllene oxide	0.3	0.5	0.2
1592	salvial-4(14)-en-1-one	-	-	0.1
1608	humulene epoxide II	0.3	0.4	t
1627	1-epi-cubenol	0.8	-	1.5
1638	epi-α-cadinol	1.5	0.6	0.7
1640	epi-α-muurolol	1.5	0.6	0.8
1644	α-muurolol	0.6	t	0.4
1652	α-cadinol	4.1	0.6	2.0
1685	germacra-4(15),5,10(14)-trien-1-al	0.6	-	0.3
1688	shyobunol	-	-	t
1715	(2Z,6E)-farnesal	0.4	1.0	-
1739	**oplopenone**	**-**	**0.3**	**-**
1933	**cyclohexadecanolide**	**-**	**-**	**0.1**
1987	**manoyl oxide**	**-**	**-**	**0.2**
2022	**abieta-8,12-diene**	**-**	**-**	**-**
2055	**abietatriene**	**-**	**-**	**0.3**
2056	manool	1.1	-	0.6
2087	abietadiene	-	-	-
2105	**isoabienol**	**-**	**-**	**0.2**
2184	**sandaracopimarinal**	**0.2**	**-**	**-**
2314	**trans-totarol**	**0.2**	**-**	**-**
2331	**trans-ferruginol**	**0.5**	**-**	**t**

KI = Kovat's Index on DB-5(= SE54) column. Compositional values less than 0.1% are denoted as traces (t). Unidentified components less than 0.5% are not reported.